LIFE B2E4SustWWTP (LIFE16 ENV/GR/000298)

New concept for energy self-sustainable wastewater treatment process and biosolids management

Deliverable: Technical report for syngas engine tests

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PARTNER (S) CONTRIBUTING	GREENE

GENERAL INFORMATION

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1. INTRODUCTION

LIFE B2E4sustainable-WWTP is a demonstration project that aims to improve the performance of overloaded (and thus, under-performing) extended aeration Wastewater Treatment Plants (WWTPs) and protect aquatic environment against pollution caused by WWTPs effluent, at significantly reduced energy requirements by means of a novel process for upfront solids removal (prior to aeration tank). Additionally, the project will demonstrate the valorization of the produced biosolids for electric energy production (through gasification), thus reducing further the net energy consumption of the WWTP, and consequently reducing the emission of greenhouse gases. The produced electric energy will be sufficient for energy self-sustainable operation for wastewater treatment.

2. GOAL

This deliverable presents the results for the task "ACTION A.1: Preliminary design for integration of microscreen, dryer and gasifier into the WWTP" relative to syngas parameters for further engine operation.

The goal of this action is the determination of optimal operational parameters of the process train consisting of the microscreening, the characteristics of the produced biosolids that will be determined the drying and valorization of biosolids by gasification tests. All tests will be performed using real municipal wastewater with a flowrate of 5 m3/h.

Through these preliminary assessments, the optimal operational parameters of the physical, chemical and biological performance in terms of cleaning capacity and energy efficiency will be studied. The results of the preliminary trials will be thoroughly analyzed and evaluated aiming at gaining reliable dimensioning values for the demo plant (Rethymno/Crete).

The activity where Greene has worked with CETEMMA directly is "Sub-action A.1.2. Preliminary study of parameters for syngas engine (CETENMA, GREEN-E)".

Before the operation of the pilot plant, CETENMA has carried out engine tests at bench scale (in his facilities) in a dual fuel engine to facilitate monitoring of the operation variables needed at the demonstration site and obtaining relevant data about the engine adaptation and control needs to optimize the production of energy by syngas.

In addition, energy production data has been worked out to design the drying system, allowing to know which quantity of heat will be supplied by exhaust gases. To do that, a prepared mix of gases has been used instead of real syngas. Prepared syngas has been obtained following bibliography and GREEN-E recommendations, since the gasification technology fed by sewage sludge is not extensively used around the world and there is a lack of data about produced syngas. Therefore, since the engine at the demonstration site will be fed with real syngas from the gasification reactor to produce energy, during this early task a mix of gases reproducing the syngas composition has been used to simulate the combustion process.

3. BIOSOLIDS GASIFICATION

Gasification is a process of conversion of any solid or liquid carbon-based material (feedstock) into gaseous fuel through its partial oxidation with air, oxygen, water vapor or their mixture. It could also be defined as the thermo-chemical process limited to a partial combustion and pyrolysis

This process can be considered as a thermochemical treatment which unlike the full combustion uses air/fuel ratios noticeably below the stoichiometric value. This deficiency avoids the complete conversion of C and H2 in CO2 and H2O and allow the formation of combustible components of syngas.

Typical composition of syngas includes components such as CO, H2and CH4, and typical products of combustion as CO2, N2, O2 or H2O.

B2E4 WWTP project will be use the energy content of biosolids produced from the micro screen by gasification and combustion of produced gas in an internal combustion engine. Based on Greene experience. Table 1 show the syngas expected composition

Composition	Expected syngas composition (% by Volume)
Carbon monoxide	17
Hydrogen	14
Methane	3
Hydrocarbon	0.2
Carbon dioxide	12
Water	14

Table 1 Syngas expected composition

There are various properties of syngas which can affect the combustion process in IC engines. Among them the most important is flammability limit which is very important characteristic in the safety and fuel for IC engine. The other one is laminar flame velocity or burning velocity an essential parameter for the investigation of combustion chamber operation and emission performance

Syngas flammability limits

The flammability limit is the generally used as index for representing the flammability characteristics of gases. It defines the range of concentration of the fuel in a fuel-air mixture at specified temperature and pressure that allows ignition initiated flame to propagate and sustain.

There are two distinct separate flammability limits for the fuel–air mixture, namely, the lower flammability limit (LFL) that is the leanest fuel-limit up to which the flame can propagate and the upper flammability limit that is the richest limit.

The lower flammability limit is an indicator of combustibility of fuels and therefore more emphasis should be given to the engine atmosphere, oxidizer (air-fuel ratio) and ignition energy for the sustainability of combustion.

Fuel Properties	**H2**	**CO**	**CH4**
Fuel LHV (MJ/kg) [MJ/Nm3]	(121) [10.8]	(10.2) [12.7]	(50.2) [35.8]
Air-Fuel Ratio (mass) [mole]	(34.4) [2.38]	(2.46) [2.38]	(17.2) [9.52]
Peak flame Temp (K) @ 1 atm	2378	2384	2223
Flammability Limit ϕ (Lean/Rich)	0.01/74.2	0.34/6.80	0.54/1.69
Flame Speed at Stoich. (cm/sec)	270	45	35

Table 2 Properties of hydrogen, carbon monoxide and methane,

Gas cleaning

The syngas exits the reactor at a very high temperature of 500e 600 ºC. Apart from a very high temperature, the syngas exits from the reactor also contain a lot of impurities such as tar and dust. In order to use syngas to run an IC engine, the temperature of the syngas has to be reduced to close to ambient temperature.

As engine run on high temperature syngas will lead to reduction in efficiency of the engine performance. A high temperature fuel mixture will reduce the filling efficiency and subsequently will reduce the performance efficiency of the engine.

The impurities in syngas also need to be reduced to ensure smooth operation of the engine. For a sustainable operation of the gasifier based power plant it is essential to have a gas cleaning system which works efficiently with a low maintenance cycle.

4. SYNGAS AS A FUEL IN INTERNEL COMBUTION (IC) ENGINE

Significant research has been performed on studying and improving the operation of ICEs fueled by syngas. The quality of syngas as a fuel is significantly poorer than gasoline and natural gas. Therefore, the engines require certain design modifications to be able to run on syngas. Many studies and experimental investigation has been done on both spark ignition and diesel engines, that were fueled with syngas and present data obtained in experimental investigations on the engine’s brake power, torque, efficiency, power de-rating, emissions, exhaust temperature and knock tendency, considering the influence of the air/fuel equivalence and the compression ratios. The main conclusions obtained after the review are presented the following sections.

4.1 SYNGAS USE SPARK IGNITION ENGINE (SI)

Syngas is a low-energy-density fuel and SI engine is having low compression ratio in the range of 8 to 12, the power degradation in SI is extensive compared to high energy- density fuels such as gasoline and natural gas

The reduction in power of an engine run on syngas is mainly due to the lower net calorific value of the air/fuel mixture[1]. The power derated to about 40-50%. About 30% power loss is due to low energy density of syngas and the rest is accounted by the pressure drop in the intake valves and piping. A spark ignition engine requires very little modification to run on syngas. Generally depending upon the compression ratio and rpm of engine, the ignition timing must be advanced by about 30-40 degrees. This is done because of low flame speed of syngas as compared to gasoline. The low flame speed of syngas is more efficiently used in low speed engine. Thus, an engine with 1500-2500 rpm is ideal for syngas application.

4.2 SYNGAS USE IN DIESEL ENGINES

Diesel engine or Compression ignition (CI) engine would operate more efficiently with syngas. Diesel engines have higher efficiency due to a greater compression ratio, (usually varies between 12 and 24) and also have better durability and, in some cases, require low maintenance than spark-ignition engines.

The main barrier to use syngas in diesel engines is that it cannot be used without a means of initiating combustion because the temperature at the end of the compression stroke is lower than the auto ignition temperature of syngas.

Therefore, to use syngas in Diesel Engine it is necessary to operate the engine in a dual-fuel mode, in which syngas is used as the primary fuel, and ignited by pilot diesel fuel with diesel fuel savings up to 85%.[2]

The basic operation of dual fuel engines is shown in . In the dual fuel engine, natural gas is fumigated with air in the intake stream by a venturi installed before the intake. Fuel gas flow is controlled by a throttle. The amount of gas admitted into the intake air stream is dependent on the engine load and speed. The mixture is compressed and a small amount of diesel fuel is injected near the end of compression stroke to initiate combustion. No modifications are made to the internal workings of the engine or the diesel injection system. The fuel gas will displace some of the diesel required to run the engine, decreasing diesel fuel consumption for the same power output.

[1] G. Sridhar, P.J. Paul and H.S. Mukunda; "Biomass derived producer gas as a reciprocating engine fuel- An experimental analysis", Biomass and Bioenergy, Vol. 21(1), pp. 61-72, 2001

[2] A.S. Ramadhas, S. Jayaraj and C. Muraleedharan; "Dual fuel mode operation in diesel engines using renewable fuels: Rubber seed oil and coir-pith producer gas", Renewable Energy, Vol. 33(9), pp. 277-2083, 2008.

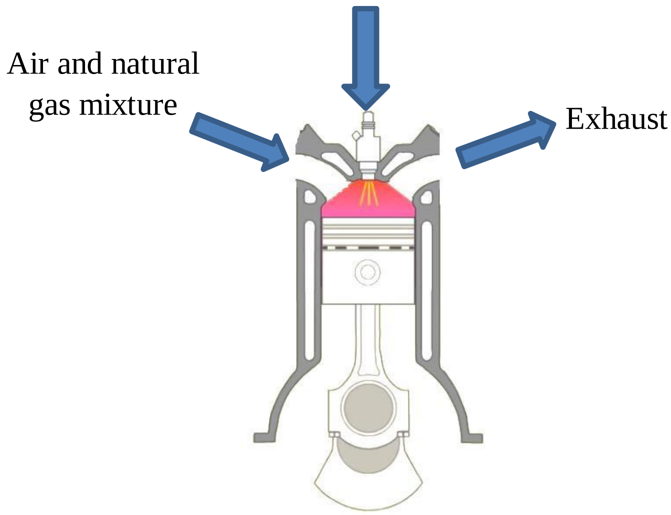

Figure 1.8: Basic dual fuel operation

CETENMA has his own adapted diesel engine to test this operation mode, therefore this mode of operation was tested to evaluate its viability.

5. MATERIALS AND METHODS

5.1 TESTBED

Test were developed at CETENMA ENGINEs LAB. These facilities internal are located at the basement floor of CETENMA building at Cartagena (Spain). This lab is focused on improving efficiency, reducing emissions, and developing efficient and environmentally friendly systems for power generators using liquid and gaseous alternative fuels.

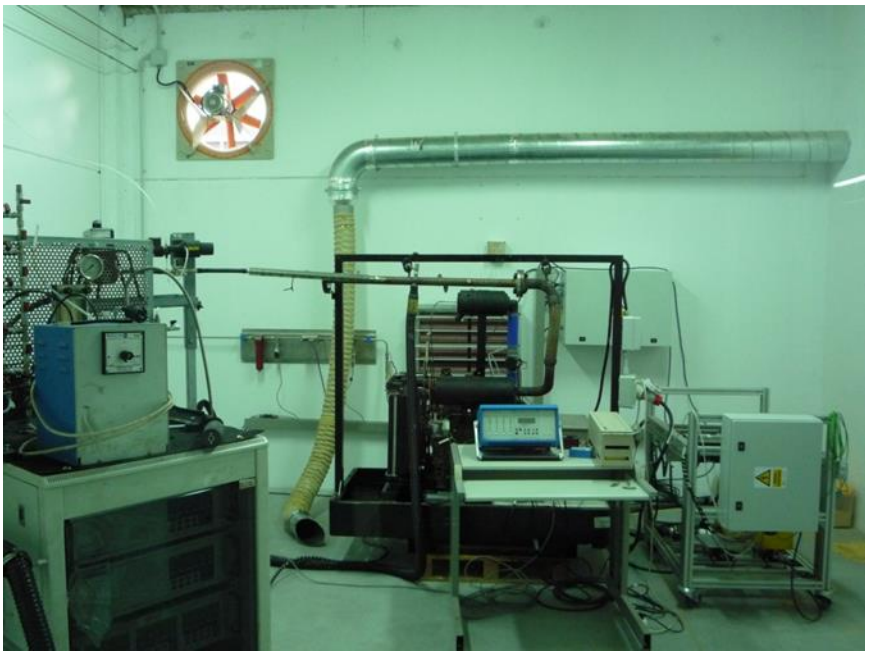

Table 3 Test bench

This research facility is equipped with the needed equipment to develop tests are performed according to different standards depending on the type of motor or the fuel to be tested (Engine performance, power curves, emissions, reliability etc.).

5.2 ENGINE TECHNICAL DATA

The engine used in this study was a naturally aspirated, four -stroke, three-cylinder diesel engine mounted on genset of with rated power of 12 kw a Table 4 shows the engine specifications used:

YANMAR

3TNV88

Engine Technical Data Revision: 0

	Unit	3TNV88-GGE
General Data		
Number of Cylinders	-	3
Engine Type	-	Inline, Water-Cooled, 4 Stroke Diesel
Bore x Stroke	mm x mm	88 x 90
Total Displacement	cc	1.642
Combustion type	-	Direct Injection
Aspiration	-	Natural Aspiration
Valves per Cylinder	-	2
Compression ratio	-	19.1
Firing Order	-	1-3-2
Performance Data		
Net Intermittent Power	HP [kW] / rpm]	21.7 [16.2]/1800, 17.7 [13.2]/1500
Net Continuous Power	HP [kW] / rpm]	19.7 [14.7]/1800, 16.4 [12.2]/1500
Net Max Torque	ft-lb [Nm]/rpm	-
Low Idle Speed	rpm	1500+/-25
High Idle Speed	rpm	1895+/-25
Physical Data		
Direction of rotation	-	Counter Clockwise (view from flywheel)
Length - Inches	Inches [mm]	23.46 [596]
Width - Inches	Inches [mm]	20.20 [513]
Height - Inches	Inches [mm]	26.18 [665]
Dry Weight	lbs [kg]	373 [169]
PTO System		
Flywheel	-	Semi SAE #4
Flywheel Housing	-	Semi SAE #4 (105 mm Depth)
Gear Case	-	without SAE Hydraulic Pump Flange
Lubrication System		
Inclination, Continuous	degrees	30
Inclination, 3 minutes Max.	degrees	35
Lubrication Oil Filter Type	-	Paper Element
Oil Capacity, Effective	Liters	2.8
Total System Capacity	Liters	6.7
Oil Change Interval, Hours	hr	250 (50, initial)
Recommended Oil Type	API	CD, CE, CF or higher grade
Cooling System		
Fan Type	-	Pusher
Fan Diameter	Inches [mm]	14.17 [360]
Number of Blades	-	6
Fan Pulley Diameter	Inches [mm]	3.54 [90]
Crank Pulley Diameter	Inches [mm]	4.72 [120]
Fuel System		
Fuel Filter Type	-	Paper Element
Fuel Injection Pump Type	-	Distributor Type
Water Separator (Standard)	-	Mesh size: 100-mesh/inch, water reservoir 150 cc
Electrical System		
System Voltage	Volts	12 V
Electric Stop Device	-	Stop Solenoid
Alternator	-	12V-40A
Starting Aid Device	-	Air Heater, 12V 400W
Standard pre-heat time	Seconds	15
Starting Motor Type	-	Reduction
Starting Motor Power	kW	1.2

Date: 07/11/2006

Doc. No.: YAE-Spec-04-0010 Page: 1/1

Table 4 . Engine technical data

The dual fuel system is a retrofit to the diesel engine. No modifications are made to the internal workings of the engine or the diesel injection system. The syngas will displace some of the diesel required to run the engine, decreasing diesel fuel consumption for the same power output.

The genset was designed to run at a speed of 1500 RPM generating three phase power at 415 V, at a frequency of 50 Hz. The engine speed tends to reduce as load increases and when the engine speed reduces the fuel pump increase the flow of fuel mixture into the engine and to maintain the engine at the design speed. When there is a reduction in the load the speed of the engine tends to increase and the pump reduce the flow of fuel mixture into the engine.

5.3 Gas fuel feed system

The original engine was modified to suit for syngas-diesel dual fuel combustion. The simulated syngas was premixed with the combustion air in the intake by throttle valve with a venturi mixer to ensure the homogeneity.

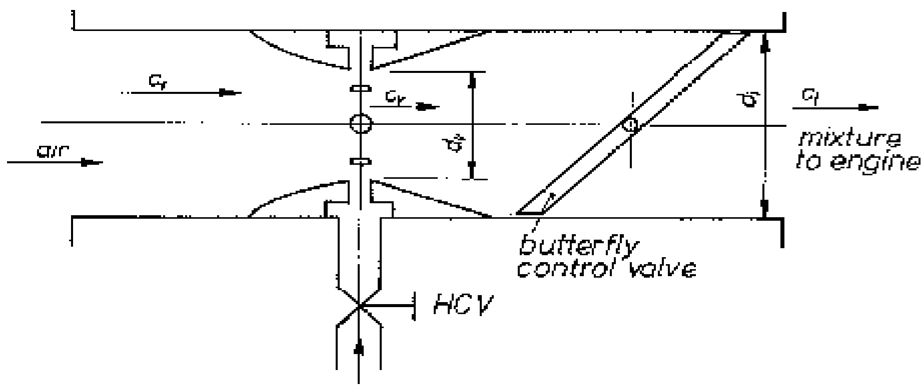

Figure 1 Venturi mixer

To deliver the syngas to the engine intake manifold the gas supply line was used. This supply line starts at outside of CETENMA facilities where the gas cylinders are installed. One of them contains the simulated syngas with the defined composition and, the other contains Nitrogen to inertize the line if some problem is detected.

The incoming gas first encounters two pressure regulators. The first regulator regulates the pressure to 5-10 bar and the second regulator reduces the pressure to approximately 2 bar. A gas shut-off solenoid valve is also included and is controlled by the programmable logic controller (PLC). It must be energized for the gas control valve to open.

A gas filter is located in the gas train to remove any particulates from the gas stream, thus protecting the control valves and the mass flowmeter. This mass flow meter (Bronkhorst High-Tech F202AV) allow measure and regulate the flow of gas that arrive to the engine intake manifold.

Attached to the diesel engine a control valve gas mixing device premixed the simulated syngas with air before entering the engine air intake manifold. The schematic of the syngas supply system is shown in Figure 1.

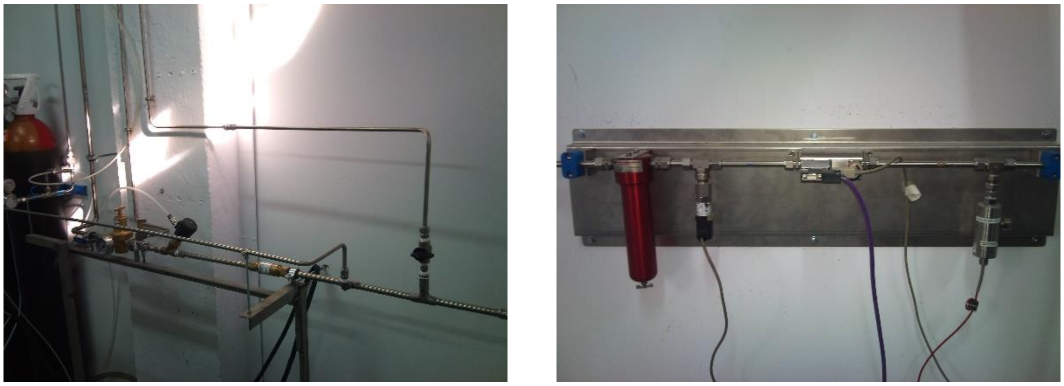

Figure 2 Syngas feeding system

At the end of the gas train, a control valve and mixer is installed. This valve is a Woodward L-Series Air/Fuel Ratio Control which could provide precise air-fuel ratio control for engines. It is a microprocessor-based actuator with built-in speed control and internal fault detection. The valve is directly mounted to the mixer between the air filter and the intake stream to ensure the complete mixing of the syngas with air.

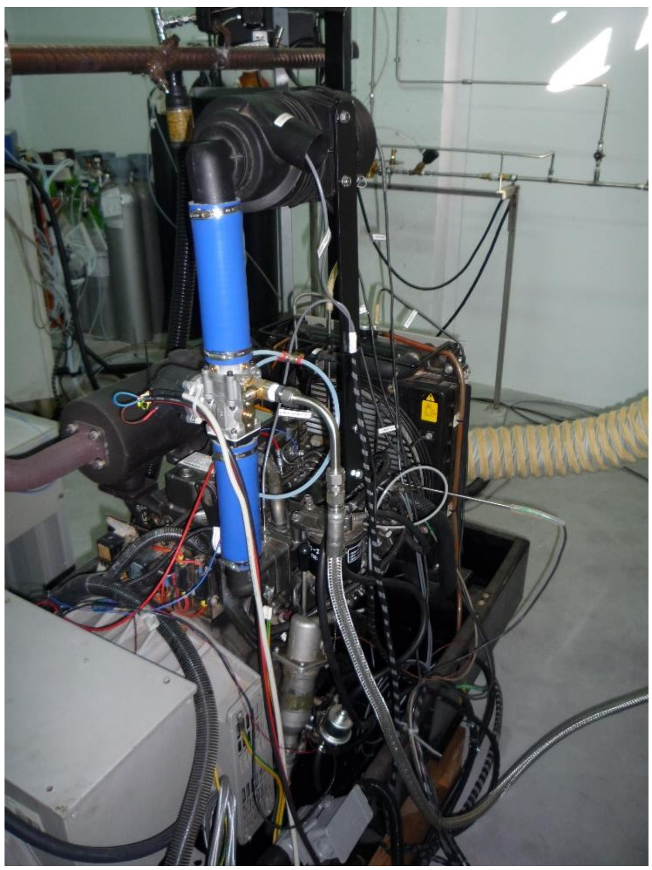

Figure 3 Detail of the mixing valve

5.4 Liquid fuel feed system

For the liquid fuel, an especial external fuel system, was used to supply the tested liquid fuel to the engine fuel pump. Diesel fuel mass flow is measured using a direct gravimetric measurement technique. The amount of fuel consumption is determined directly by measuring the time related weight decrease of the measuring vessel by means of a load cell.

Table 5 Liquid fuel meausremente system

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5.5 Power measurement

Effective power is measured using a Siemens SENTRONPAC2300 power analyzer. The generated energy could be measured under different loads using a resistive load bank that dissipate the energy.

Figure 4 Power meausrement and resistive load

5.6 EXHAUST GAS MEASUREMENT

Emission analysis was conducted with a TESTO 350XL integrated emissions analyzer. The probe was inserted into the exhaust pipe. Once the analyzer is in operation, the pump inside the device withdrew a sample of the exhaust gas. This sample was conditioned before entering the analyzer, via an onboard cooling systems, different filters and a water trap.

The analyzer are equipped with electrochemical sensors to measure Carbon Monoxide, Nitric Oxide, Nitrogen Dioxide, Oxygen and Unburned Hydrocarbons (THC).

Next table show the para

GAS	Measurement range	Accuracy	Resolution	Response time
O2	0 – 25 % Vol	±5 ppm (0 hasta +99 ppm)	1 ppm	30 s
CO	0 – 10000ppm	±10 ppm (0 hasta +199 ppm)	1 ppm	40 s
CO2	0 - 50 % Vol.	±0,3 % Vol. + 1 % del v.m. (0 hasta 25 % Vol.) ±0,5 % Vol. + 1,5 % del v.m. (25 hasta 50 % Vol.)	0,01 % Vol. (0 hasta 25 % Vol.) 0,1 % Vol. (> 25 % Vol.)	10 s
NO	0 – 300 ppm	±2 ppm (0 hasta +39,9 ppm)	±0,1 ppm	30 s
NO2	0 – 500ppm	±5 ppm (0 hasta +9,99 ppm)	0,1 ppm	40 s
SO2	0 – 5000ppm	±5 ppm (0 hasta +99 ppm)	1 ppm	30 s
CxHy				

Table 6 Specifications and measurement technology of the 5-gas emissions bench

5.7 In cylinder pressure

The in-cylinder pressure history of combustion cycles was measured using a piezoelectric with a PCB 112B10 pressure transducer in conjunction with a 1 ° crank-angle encoder to identify the piston location. Also pressure at intake manifold was measured using KISTLER 4007C piezoresistive transducer. Table X shows the sensors and the signal amplifier used in this study

	INTAKE	CYLINDER
SENSOR	KISTLER 4007C	PCB 112B10
AMPLIFIER	KISTLER 4624A	KISTLER 5018A

Table 7 Sensors and amplifiers used

An engine measurement system based on National Instrument's Compact Rio architecture is used to do the data acquisition, This system was developed joint UPCT. In-cylinder pressure and main operation parameters could be monitored with an own developed graphical user interface.

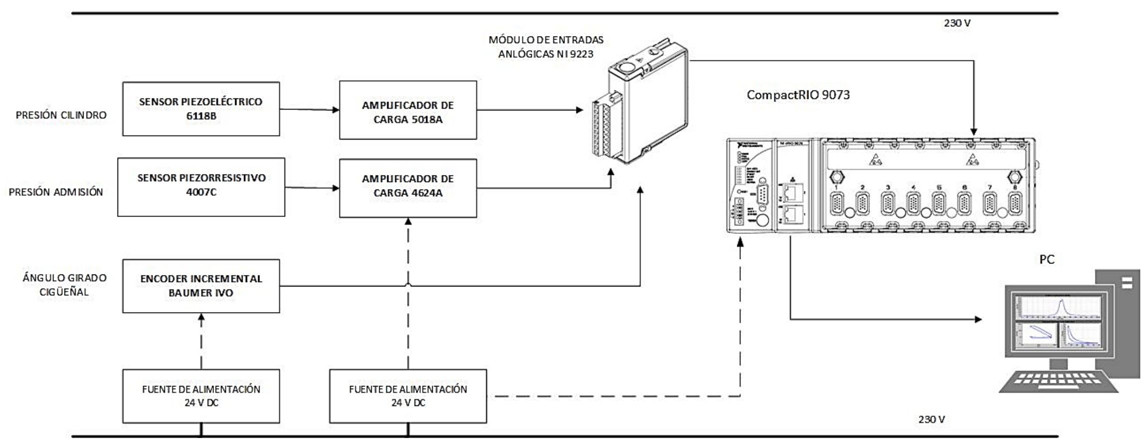


Figure 5 Architecture of the measurement chain

5.8 Operation Conditions

Ambient temperature, humidity and other parameters of engine operation (pressure and temperature of intake air, exhaust gas temperature, oil and water temperatures) were measured and recorded with the laboratory data logger.

6. TEST PLAN

Detailed evaluation of syngas's combustion parameters and their effect in an internal combustion engine is required to determine overall performance and emissions. To develop this task, the following activities have been carried out:

Firstly, preliminary determination of the system's measurements, assembly and calibration.

- System adjusted for data acquisition.
- Establishment of engine operation variables for measurement and control, as well as the degree of engine loading.

Once the measurement system was adjusted, tests to obtain power, fuel consumption (following ISO 3046), emissions and gases opacity from combustion of sample gases: .

- The first task developed to identify the upper limit of the syngas use, was define the diesel baseline operating the engine with dual fuel system turned off.
- A Stantdard Petroleum diesel fuel was used for basic engine testing under a normal diesel operation without any modification being made to the engine.
- Once the baseline was defined, different test were done increasing the amount of syngas at regular step regulating the syngas flow with the mass flowmeter.
- At each load as soon as the additional gas supplied tries to speed up the engine, the governor cuts down the diesel flow to maintain the speed
- To detect abnormal combustion cases the evolution of the cylinder pressure against crank angle for the different volume of syngas were observed.
- The diesel displacement represents the percentage of fuel gas substitution in the diesel engine. Diesel displacement is calculated using Equation 1 where m is mass flow rate, LHV is lower heating value. The subscripts syngas and D represent syngas and diesel, respectively

$$Substitution\ \% = \frac{\text{m\_syngas} * 〚\text{LHV}〛\text{\_syngas}}{(\text{m\_syngas} * 〚\text{LHV}〛\text{\_syngas} + \text{m\_diesel} * 〚\text{LHV}〛\text{\_diesel})}$$

Equation 1 Diesel substitution

- Tests were conducted for the diesel engine with dual fuel system turned off (diesel baseline) and for normal dual fuel operations.
- The air inlet temperature was maintained around 25 °C, and the fuel line temperature was approximately 30 °C. Measurements were recorded at 1500 rpm and a full load.

Once all the measurements at the test have been carried out, the treatment of data have been studied, together with a comparative study of power and fuel consumption and gases opacity.

- In addition, the following information has been obtained:
  - Tools for remote monitoring of the engine operation necessary to operate in the DEMO site.
  - Quantity of heat to be supplied by engine in the drying system.

7. RESULTS

7.1 Preliminary results

In the first experimental program, the test had to be finished at 28% of energy substitution cause the gas flow was limited by the installed mass flowmeter. This flowmeter was calibrated up to 75 l/min

The main results of this test are shown in the Table 8 Preliminary test results

LOAD	%	85%	85%	85%	85%	85%
	KW	10	10	10	10	10
DIESEL CONSUMPTION	g/h	2502	2142	2034	1926	2376
DIESEL CONSUMPTION	kg/h	2,502	2,142	2,034	1,926	2,376
GAS CONSUMPTION	LN/min	0	37,5	52,5	67,5	0
GAS CONSUMPTION	m3/h	0	2,25	3,15	4,05	0
Energy Content Liquid	Mj	107,14	91,72	87,10	82,47	101,74
Energy Content Gas	Mj	-00	14,98	20,97	26,97	-00
Exhaust Gas	º C	285,00	319,00	323,45	326,00	319,00
Equivalent Diesel Consumption	kg	2,50	2,49	2,52	2,56	2,38
Sustitution	%	0%	14%	19%	25%	0%
% O2	%	11,24	10,43	10,32	10,13	11,32
ppm CO	ppm	283,67	2.226,37	2.484,82	2.863,02	89,72
ppm NO	ppm	478,83	367,18	360,92	343,08	558,33
ppm NO2	ppm	9,30	16,53	15,66	15,38	8,30
[ppm] CxHy	ppm	2.255,00	3.205,67	3.513,17	3.565,83	1.320,17
NOx	mg/m3	1.847,17	1.339,13	1.301,12	1.217,70	2.159,45
%CO2	%	7,20	7,80	7,89	8,02	7,14
[°C] IT	ºC	27,20	27,69	28,00	28,20	28,58
[°C] TDGS	ºC	41,23	42,27	42,41	42,67	41,13
°C VT	ºC	23,87	24,39	24,32	24,66	24,49

Table 8 Preliminary test results

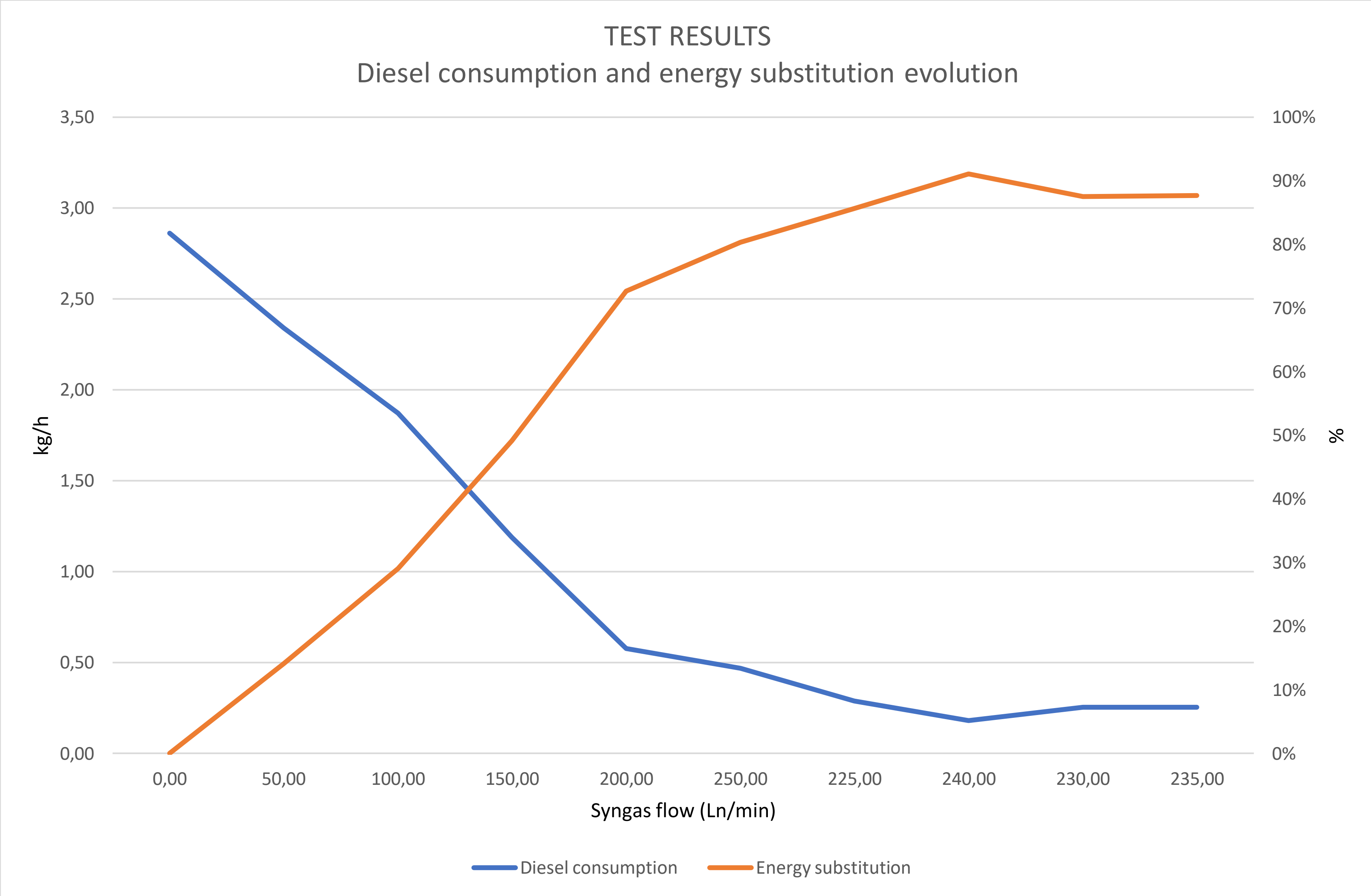
7.2 Second experimental program test results

To solve the problem with the syngas flow limit, a new mass flow meter was installed and a new weighing system to ensure the flow measurements.

Figure 6 Gas cylinder scale

At each step, diesel replacement was measured using the energy substitution rate and the in-cylinder pressure were analyzed. Individual test reports are attached.

LOAD	%	100	100	100	100	100	E	100	100	100	100
	KW	**11.712**	**11.948**	**11.954**	**11.956**	**11.954**	**11.972**	**12.031**	**12.015**	**12.003**	**11.994**
DIESEL CONSUMPTION	kg/h	2,86	2,34	1,87	1,19	0,58	0,47	0,29	0,18	0,25	0,25
GAS CONSUMPTION	LN/min	0,00	50,00	100,00	150,00	200,00	250,00	225,00	240,00	230,00	235,00
	m3/h	0,00	3,00	6,00	9,00	12,00	15,00	13,50	14,40	13,80	14,10
	kg/h	-00	3,44	6,89	10,33	13,78	17,22	15,50	16,53	15,84	16,19
Energy Content Liquid	Mj	122,55	100,20	80,16	50,87	24,66	20,04	12,33	7,71	10,79	10,79
Energy Content Gas	Mj	-00	16,41	32,82	49,23	65,64	82,05	73,85	78,77	75,49	77,13
Equivalent Diesel Consumption	kg	2,86	2,72	2,64	2,34	2,11	2,38	2,01	2,02	2,01	2,05
Sustitution	%	0%	14%	29%	49%	73%	80%	86%	91%	87%	88%
Exhaust Gas	º C	510,83	509,16	516,61	492,63	481,77		446,79	490,66	486,21	491,71
% O2	%	8,48	7,84	6,98	6,81	5,32		4,44	3,56	4,14	4,21
ppm CO	ppm	238,00	1.976,97	3.932,00	3.541,00	3.048,00		2.968,00	2.596,48	2.774,00	2.499,00
[ppm] CxHy	ppm	348,00	364,70	513,00	513,00	535,00		579,00	516,00	548,00	501,00
NOx	ppm	525,00	358,00	260,30	230,00	186,00		188,00	195,00	195,00	208,00
%CO2	%	9,62	11,09	12,73	14,45	16,48		17,41	18,75	17,98	18,61
Mass Flow of wet exhaust gas m_esc,w	g/h	69.549,46	90.943,99	97.392,62	95.482,08	86.728,05		81.891,80	79.074,23	80.821,33	82.252,23
		69,55	90,94	97,39	95,48	86,73	ENGINES STOP	81,89	79,07	80,82	82,25
Specific heat capacity (Cp)	kJ/kg K	0,95	0,98	1,00	1,04	1,03		1,01	1,02	1,02	1,05
Fuel power, m_f H_f	kW	34,04	33,38	33,37	30,78	29,05		28,40	28,78	28,53	29,08
Sensible heat of Exhaust gas, H_esc,w	kW	8,81	11,82	13,17	12,75	11,18		9,66	10,34	10,45	11,04
	%	0,26	0,35	0,39	0,41	0,38		0,34	0,36	0,37	0,38


TEST RESULTS
Diesel consumption and energy substitution evolution
3,50
3,00
2,50
2,00
1,50
1,00
0,50
0,00
kg/h
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
%
0,00
50,00
100,00
150,00
200,00
250,00
225,00
240,00
230,00
235,00
Syngas flow (Ln/min)
Diesel consumption
Energy substitution